

10/540216

PCT/CA2003/001987

WO 2004/057554

JC17 Rec'd PCT/PTO 10 JUN 2005

**Virtual simulator method and system for neuromuscular training and certification  
via a communication network**

**Field of the invention**

The field of the invention is related to professional work, labour or craft activities, sport or even physical rehabilitation requirements where the skills, dexterity or neuromuscular ability is required to performed physical activities in a precise environment with electronic tutoring systems and methods, and more particularly, to an interactive computer-based training system and method operable over an Internet Protocol (IP)-based public computer network such as the Internet, a corporate Intranet, and the like. This precise environment can be located in a online database for code of conduct, state-of-the-art, physic laws or technical code for physical activities requiring training and certification.

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**Summary of the invention****JC17 Rec'd PCT/PTO 15 JUN 2005**

By practicing online virtual certification over the Internet and the World Wide Web, it has become obvious that a technological gap exists between traditional certification and online certification. This gap is related to the fact that there is no available technology in the Internet Protocol (IP)-based public computer network such as the Internet, corporate Intranet or the like for the physical and cerebral training to accomplish a minimum dexterity required by code, rule of the art or any physical function requiring minimum requirements related to neuromuscular activities.

For example, an online 2D, 3D, near 3D visual multimedia signal and auditory signal can create an environment that could easily simulate visual inspection, non-destructive examination or destructive examination to ensure neuromuscular workmanship or craftsmanship requirements or skill training dexterity. Instead of learning by traditional manual approach, a simulator method develops all the minimum requirements needed in profession, industry, field, sport or rehabilitation activities.

The implementation of virtual simulator method and system are also intended to help the trainee to learn a technique and not to cope with difficult environment. For example, in a traditional welding training center, the welder trainee has first to compose with the difficult environment of the welding electric arc (eye protection and gaseous emanations and other complex technical considerations). Also in a typical approach, a trainee can easily spare a very considerable amount of money before handling very expensive material and technology.

According to the present invention, there is provided a virtual simulator system for neuromuscular training and certification via a communication network, comprising:

a database connectable to the communication network, the database storing data relative to a code of conduct, state-of-the-art, physics law equations, technical code and technique for physical activities requiring training and certification for a user, and training scenarios complying with the code of conduct, state-of-the-art, physics law equations, technical code and technique;

a multimedia device connectable to the communication network, the multimedia device having a stopwatch circuit and an input device for interaction with a user; and

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an on-line simulator processor connectable to the communication network, the on-line simulator processor performing operations comprising:

retrieving data representative of one of the training scenarios from the database in response to a user selection on the multimedia device;

generating test elements, parameters and controls based on the data;

monitoring online use of the input device by the user;

performing calculations of a simulated environment on time and online in response to the use of the input device by the user and management of the test elements, parameters and controls by the user;

generating real time images on the multimedia device replicating the simulated environment according to the management of the test elements by the user as a function of run-time data provided by the stopwatch circuit; and

recording the test elements in the database.

According to the present invention, there is also provided a virtual simulator method for neuromuscular training and certification via a communication network, comprising the steps of:

storing data relative to a code of conduct, state-of-the-art, physics law equations, technical code and technique for physical activities requiring training and certification for a user, and training scenarios in a database connectable to the communication network;

providing a multimedia device connectable to the communication network, the multimedia device having a stopwatch circuit and an input device for interaction with a user; and

through an on-line simulator processor connectable to the communication network, performing operations comprising:

retrieving data representative of one of the training scenarios from the database in response to a user selection on the multimedia device;

generating test elements, parameters and controls based on the data;

monitoring online use of the input device by the user;

performing calculations of a simulated environment on time and online in response to the use of the input device by the user and management of the test elements, parameters and controls by the user;

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generating real time images on the multimedia device replicating the simulated environment according to the management of the test elements by the user as a function of run-time data provided by the stopwatch circuit; and

recording the test elements in the database.

According to the present invention, there is also provided a multimedia device connectable to a virtual simulator system having an on-line simulator processor and a database for neuromuscular training and certification via a communication network, comprising:

a stopwatch circuit;

an input device;

a user interface;

a port for communication with the on-line simulator processor through the communication network; and

a processor connected to the stopwatch circuit, the input device, the user interface and the port, the processor comprising means for:

transmitting data produced by use of the input device on the user interface to the on-line simulator processor via the port;

receiving test elements, parameters and controls and simulated environment data from the on-line simulator processor via the port;

monitoring a management of the test elements, parameters and controls by the user as a function of run-time data provided by the stopwatch circuit; and

displaying real time images on the user interface replicating a simulated environment using the simulated environment data according to the management by the user.

According to the present invention, there is also provided an apparatus for neuromuscular training and certification on a multimedia device via a communication network, comprising

a database connectable to the communication network, the database storing data relative to a code of conduct, state-of-the-art, physics law equations, technical code and technique for physical activities requiring training and certification for a user, and training scenarios complying with the code of conduct, state-of-the-art, physics law equations, technical code and technique; and

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an on-line simulator processor connectable to the communication network, the on-line simulator processor performing operations comprising:

retrieving data representative of one of the training scenarios from the database in response to a request received from the multimedia device representing a user selection;

generating test elements, parameters and controls based on the data;

communicating the test elements, parameters and controls to the multimedia device;

monitoring user activity data received from the multimedia device;

performing calculations of a simulated environment on time and online in response to the user activity data in relation with the test elements, parameters and controls;

transmitting simulation data to the multimedia device causing the multimedia device to generate real time images replicating the simulated environment according to the user activity data; and

recording the test elements in the database.

According to the present invention, there is also provided a computer readable memory having recorded thereon statements and instructions for execution by a computer system to carry out the above method.

According to the present invention, there is also provided a computer program product, comprising:

a memory having computer readable code embodied therein, for execution by an on-line simulator processor, for neuromuscular training and certification via a communication network, said code comprising:

code means for storing data relative to a code of conduct, state-of-the-art, physics law equations, technical code and technique for physical activities requiring training and certification for a user, and training scenarios in a database connected to the communication network; and

code means for retrieving data representative of one of the training scenarios from the database in response to a user selection on a multimedia device connected to the communication network;

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code means for generating test elements, parameters and controls based on the data;

code means for monitoring online use of an input device on the multimedia device by the user;

code means for performing calculations of a simulated environment on time and online in response to the use of the input device by the user and management of the test elements, parameters and controls by the user;

code means for generating real time images on the multimedia device replicating the simulated environment according to the management of the test elements by the user as a function of run-time data provided by a stopwatch circuit of the multimedia device; and

code means for recording the test elements in the database.

According to the present invention, there is also provided a carrier wave embodying a computer data signal representing sequences of statements and instructions which, when executed by an on-line simulator processor, cause the on-line simulator processor to perform a virtual simulation for neuromuscular training and certification via a communication network, the statements and instructions comprising the steps of:

storing data relative to a code of conduct, state-of-the-art, physics law equations, technical code and technique for physical activities requiring training and certification for a user, and training scenarios in a database connected to the communication network; and

retrieving data representative of one of the training scenarios from the database in response to a user selection on a multimedia device connected to the communication network;

generating test elements, parameters and controls based on the data;

monitoring online use of an input device on the multimedia device by the user;

performing calculations of a simulated environment on time and online in response to the use of the input device by the user and management of the test elements, parameters and controls by the user;

generating real time images on the multimedia device replicating the simulated environment according to the management of the test elements by the user as a function of run-time data provided by a stopwatch circuit of the multimedia device; and

recording the test elements in the database.

According to the present invention, there is also provided a memory for storing data for access by an application program being executed on a data processing system, comprising:

a data structure stored in the memory, the data structure including information resident in a database used by the application program and including:

code of conduct data;

state-of-the-art data;

physics law equation data;

technical code and technique data for physical activities requiring training and certification for a user; and

training scenarios complying with the code of conduct, state-of-the-art, physics law equations, technical code and technique, to be used by the application program to generate test elements, parameters and controls for neuromuscular training and certification via a communication network.

The following provides a non-restrictive outline of certain features of the invention more fully described herein after.

The present invention relates to a virtual simulator method and system for neuromuscular training and certification of profession, trade, craft, sport or rehabilitation activities via a communication network and more particularly to an online multifunctional virtual training platform which implements certain predefined certification neuromuscular standards. Such method and system, which can be viewed as a service, are particularly useful for enhancing communication and exchanges between trainer and trainee seeking training with third party witnessing services for certification purposes.

Any physical activities that require a minimal dexterity requirement can benefit from this invention. For example it is common knowledge that neuromuscular skills (by opposition of neurocerebral skills) are essential for basic requirement of specialized physical activities for a professional work, labour or craft activities, sport or even physical rehabilitation.

Neuromuscular virtual online training or certification can be simulated, for example, for speed control, acceleration, strength, precision or any neuromuscular abilities related to a direct relation with physical action and neurological responses.

For example, skill ability for a profession, trade, craft or sport example could be welding. The welding ability to perform a sound weld according to code requirement is of a particular interest since it could involve safety, liability and life duration of assembled material. In the field of welding, many scientific relations between welding variables are known by experts but no relation between welder dexterity and state-of-the-art equations have been documented yet. This approach can minimize physical test cost. These costs could increase easily when the test material is technological (welding station, welding consumables and metal plates and specialist's time). One prototype of such a Web site is under confidential research and development in the online virtual certification site of WWW.EDUWELDING.COM, for the assignee of the present application. This site provides an example of one possible implementation of this invention. The site is used as an online training tool by school, association, certification bureau, consumable or equipment supplier, plant or shop. Such organisms can access updated information about the trainee member status and related information about all the steps involved in the training and certification of this welding process trainee. The member can disclose some of this information to a third party in the course of their technical or business relationship with that member. This Web site contains a welding virtual simulator method and system able to demonstrate to a trainer or a third party the ability of a trainee. This virtual simulator method and system are also able to help the trainer to isolate the specialized neuromuscular skills that the trainee has to practice to insure himself of good results when over a demonstration of his skills is required.

With the help of physic laws equation such as dynamic, mechanic of fluid and thermodynamic, the dexterity of the welder can be demonstrated by an online virtual simulator method and system to a trainer, immediate superior or certification representative for learning curve demonstration or for code minimum requirements. Prior to a physical test or to an online third party witnessing operation, a database configuration with the processor is performed to ensure sound weld, weld size, maximum root penetration with metal transfer mode used in conjunction will the welding parameter settings.

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This virtual simulator method and system can enable any weld assembly and fulfills all criteria of a welder test such as defined by a welding code by simply activating a computer screen signal by the multimedia device. A good example of this online neuromuscular virtual simulator method and system applied in the field of welding is a traditional T joint assembly of a weld assembly (fig. 12) to insure efficient weld penetration and weld size achievement without other code defect such as porosity, cracks or undercut. Code compliance and trainee, trainer and/ or third party witnessing expert receives information from the virtual simulator method and system according to authorized request.

This above example of neuromuscular training for welder is described hereafter with the help of the drawings.

It also serves to structure steps and processes implemented by companies for quality, cost and delay controls and other purposes. This leads to more efficient dissemination of information about the qualifications and competencies of persons being certified with the present invention. It therefore leads to a wider recognition of trainees for companies and other organizations using the invention.

Preferably, the manual dexterity virtual simulator method and system with the third party witnessing method involve the use of a system as described in Can. Pat. No. 2,311,685 issued to Choquet. Such a manual training is advantageous in that it permits a controlled input of essential variables to required tasks with third party witnessing certification.

**Background of the present invention**

Training method or simulator devices are in the art. There is a wide list of methods and devices reproducing a physical activity where human skills are of main concerns. But they are all related to an hardware simulator. The term hardware simulator is commonly used in the trade because the vast majority of simulators require hardware tools associated software to accurately help a user to perform his/her physical activities and an object to complete the simulated task . Typical simulators of this type are shown, for example, in the following patents documents:

FR 2 827 066	Dasse Michel & Streib Dominique
US 6 477 665	Bowman-Amuah; Michel K.
US 6 371 765	Wall et al
US 6 098 458	French & Ferguson
US 6 056 556	Braun et al
US 6 033 226	Bullen et al
US 5 320 538	Baum; David R.
US 4 931 018	Herbst et al
US 4 680 014	Paton et al
US 4 124 944	Blair; Bruce A.

Though such simulators have achieved considerable popularity and possibly commercial success, there has been a continuing need for improvement. Summary of the present invention does not need any particular hardware simulator to reproduce the training environment. Its interest resides in the software control and management of neuromuscular data collected over image collection simulating environment where the skill or dexterity is of major concern to accomplish a minimum requirement by code, rule of the art or any physical function requiring minimum requirements related to neuromuscular activities.

**Description of the preferred embodiments**

Referring to Figure 1, training scenarios are retrieved from the information system database 2 and then processed by the neuromuscular simulator processor 1 to the required trainee level. The data storage will be kept in virtual database 3 referring to figure 3, there is shown a detailed open training database center site 36.

A description will now be given, in detail, of an embodiment in accordance with the present invention. The present invention is not restricted to this embodiment.

Referring to figure 4, there is shown a welding scenario flowchart detailing a general training process followed by the system according to the present invention. The retrieved welding scenario 43 is processed online to ensure code and trainee accurate revision status. Welding training scenarios are multimedia information. Specific information about the input of welding training scenarios is shown in figure 10 and 11.

Looping step 44 is responsible to verify the welding configuration validation with code requirement and state-of-the-art physical activities. Welding configuration, code requirements are managed in this loop until scientific and code requirements are met.

Referring to figure 5, there is shown a sequence for updating a welding training scenario.

Referring to figure 6, there is shown an operation flow of the training/ certification method for the welding scenario, an operation flow of accepting or registering a new member site and a layout example of the authentication database 35.

Referring to figure 7, there is shown an operation flow of training/ certification steps and interface display for the welding scenario.

Referring to figure 8, there is shown an example of a welding card holder.

Referring to figure 9, there is shown an example of online welding certification checklist traceability of welder test scheduling of qualification of the welder/ welding operation, machine welders and welding operator qualification test planning sheet.

Figure 10 to 20 show the virtual simulator method and system method interface according to a preferred embodiment related to welding training. The system has client stations connected to a server station. Referring to figure 2, each work station may comprise a computer, a monitor and one or many input devices. These input devices will allow the trainee to increase realism of his operation by capturing displacement and orientation information. Examples of such motion capture input device known are conventional mouse, 3D mouse, touch screen, keyboard, electronic pencil or even bend and twist sensitive input strip. These input devices are examples but this invention is not limited to those. The client station may be used for different purposes, according to the access rights allocated to the user. For example, a trainee will have rights for performing various tests but will of course have no rights to change some data like his/her test results, his/her skill level. Such rights will possibly be granted to the trainer. Other rights will be granted to the certifying third party.

Welding data sheets such as figure 10 help welding trainee to set-up their work environment to perform optimize weld results. For example this welding data sheet will be used to configure the online virtual simulator system (figure 11).

Referring to figure 11, the simulator has an interface for interaction with the trainee. The interface can be conveniently provided by the monitor of the computer used by the trainee.

Referring to figure 10, there is shown an example of weld transverse cut 102. These cuts vary according to the weld preparation. A double U groove weld preparation 101 is shown. Different shapes can be simulated by this Process Data Sheet (PDS). A list of simulation shapes possibilities can be identified in reference named "ANSI/AWS D2.4, Standard Symbols for Welding, Brazing, and Non-destructive Examination". This PDS is an equivalent of a frame taken out from a animation movie such as a multimedia video. In other words, this PDS image is an animation picture extract shot representation of a weld transversal cut with the list of essentials variables that defined it.

Referring again to figure 11, the interface has a first window section in which the elements 105 to 128 used in the test are displayed. Another window section displays

test parameters and controls 129 to 134 for interactively adjusting them if necessary. The simulator generates these elements based on preset data retrieved from 36 (shown in figure 3) item 36 database. The neuromuscular processor simulator does the required calculation on time and online in response to the starting procedure set in motion by the trainee with an input device (e.g. a mouse) and produces an image e.g. elements 135 to 138 that replicates a weld bead according to the welding parameter management by the trainee.

For example, two part of metal 135 and 136 are assembled in a proper position and essentials variables 105 to 134 are set in a proper manner to produce sound welds according to code criteria. When these essential variables are used in conjunction with a multimedia device that will allow a computer screen to receive signal 137 a virtual image of a weld 138 is obtained. This image can be processed to certify code and rule-of-the-art compliance. An unlimited application possibility of this method can be developed for any neuromuscular activities.

The objective of the trainee is to obtain a sound weld with a good management of his welding parameters. Sound weld are defined in welding code or handbook. An example of a good weld can be visualized in macrographic cut as shown in figure 12. This result can only be viewed after destructive test and cannot be monitored during welding with conventional welding technology.

Referring to figure 13, there is shown that the essential variables of the simulator

system are adequately configured with the motion capture input device cursor help  that is set in motion by the motion capture input device such as a computer mouse. For example, figure 13 illustrates a simulation of the figure 12. This case is the welding set-up of 2 6"X6"X 3/8" alloy 6061-T6 aluminum plates aluminum with 0.045" diameter filler aluminum alloy 4043 in the horizontal position. The generally recognized dimensional code requirement size of the weld is 6mm (1/4") minimum with a convexity of 3 mm (1/8") maximum and a minimal penetration of 2 mm (1/16"). Therefore with the

motion capture input device cursor , the trainee adjusts the current source to a wire

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speed adjustment, just like in real situation. In the illustrated example, the current source is activated for 250 amps.

The trainee test acceptance criteria will be in accordance with the generally recognized code requirements.

When the trainee considers that the test set-up is adequate, he/ she must affix the mouse cursor  at the starting point of the assembly as shown in figure 14 for the tool positioning process. As soon as the trainee clicks on the motion capture input device, in this case a computer mouse, the neuromuscular simulator processor is started and activates a time calculation required for result output. In this patent application, this operation is visually shown by the build-up of an virtual hot-spot 1 (fig. 14). The trainee then must move the hot-spot created by the mouse cursor on the plates to join contact axis to demonstrate a sound weld. This kinematic translation operation from a start to a stop with the mouse cursor  leave a virtual metal deposition 3 (fig. 15) similar as in a real time welding operation. Kinematic law equations such as displacement, speed and acceleration are of the important criteria but the straightness of the cursor motion is also. This precision is in the millimeter range.

As soon as the trainee clicks on the motion capture input device, in this case on the computer mouse, an instruction is given to the neuromuscular simulator processor to calculate a material deposition rate which coincides with an image simulating the real aluminum weld deposition. For example, this processor calculates the liquid state aluminum flow rate as long as the welder trainee will not have release the input device trigger which in this particular case is the computer mouse. If the trainee operates in a variable bracket combination which allows him/ her to deliver a welded zone according to the training requirements, then the result will be a sound weld and considered without defect. If he does not operate according to the ideal training requirements or according to the rules of the art or the codes foreseen for that purpose, this deposited metal mass in the operating zone will have the consequence to create defects which will be visible as shown in Figure 15.

Referring to figure 15, there is shown a start-and-stop half-distance which is known in the field of welding as the compulsory stop-departure in the middle of the weld of an

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assembly test. This stop-and-start zone is always a potential zone of defects and the restart has to be in accordance with the code currently recognized in the field. The trainee handles the motion capture input device cursor quite like he would handle a welding gun trigger. The trainee has to maintain a constant speed and aim to maintain the straightness of the path to deliver a sound weld. His/ her 2nd start on the stop will be also visually inspected. It's because the demonstration of a stop-and-stop is also a factor of success or failure during a welder test.

Referring to figure 16, there is shown that during the welding when the speed is too big or small or when the cursor is not well positioned, error messages appear "Incorrect deposition" or "insufficient penetration ". These error messages are examples of the possible monitoring with the neuromuscular simulator. Others on-time process monitoring during welding are possible such as "Undercut", "Porosity" or "Cold lap".

Referring to figure 17, when the weld is completed the neuromuscular simulator processor stops the stopwatch and allows then to compare the speed with the real case which is required according to the data banks which are available to this neuromuscular simulator processor. A trainee auto-evaluation is always possible and if he/ she requires it, a virtual non-destructive or destructive visual exam is then possible by the trainer or any other online third party required to ensure welding code requirement compliance.

The trainee can then repeat as often as he/ she wishes it or as often as he/ she is allowed in the training environment by pushing button 4 (fig. 17) for a complete visual inspection, non-destructive examination or destructive examination result of a neuromuscular test. Referring to figure 18, the various results obtained allow the trainer and the third party witness or the certification representative to observe a detailed quality and defects retracability report obtained according to build-up of his training program. Referring to figure 20, by experimenting several times the welding parameters, the trainee builds-up a learning curve. The trainee can re-experiment the weld deposition as often as he/ she wants and a learning curve file built-up as much as he/ she builds-up results.

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The trainee will also see the visual test results or defects not usually available as soon as the weld is completed. For example, the trainee will see the weld bead with root lack of penetration, insufficient weld side or weld bead convexity not according to code.

A learning curve is also available to the trainee, for the trainer or for the third party witnessing auditor if required. All or only the decision-making person will decide if the trainee is then capable to switch to the stage of the practical tests with real welding equipments and consumables.

Referring to figure 19, the produced mathematical curves allow to generate a big number of images or numeric signals which shall be used to improve the training program and generate also more complex functions such as the examples described below.

- Visual exams (according to acceptance criteria code)
- Non-destructive exams: (ultrasonic, X-rays, magnetic particle and liquid penetrant)
- Destructive exams: (bending, tension, fracture, macrography)
- The complete path generated could be saved and be used on a welding programmable machine for a possible repetitive use
- Onsite and online welding robot guidance with remotely located expert using existing vision system

**Brief description of the drawings**

The objects and features of the present invention will become more apparent in conjunction with the accompanying drawings:

Figure 1 is a block diagram showing a simulator system according to the present invention.

Figure 2 is a schematic diagram illustrating a training station.

Figure 3 is a schematic diagram illustrating a system according to the present invention.

Figure 4 is a flowchart showing a general process followed by the system according to the present invention.

Figure 5 is a flowchart showing a database consulting process followed by the system according to the present invention.

Figure 6 is a flowchart showing an operation flow of different user interactions in the system according to the present invention.

Figure 7 is a flowchart showing an operation flow of certification steps & interface display in the system according to the present invention.

Figure 8 is a diagram showing an example of a card holder used in the system according to the present invention.

Figure 9 is a diagram showing an example of an online certification checklist used in the system according to the present invention.

Figure 10 is a diagram showing an example of a list of essential variables for certification use in the system according to the present invention.

Fig. 11 is a multimedia shooting view of a Virtual Dexterity Simulator (VDS).

Fig. 12 is a view illustrating a macrographic cut of a real welding assembly.

Fig. 13 – 17 are schematic diagrams showing the simulation process at different stages according to the present invention.

Fig. 18 is a schematic diagram illustrating loop result of non-satisfactory neuromuscular tests.

Fig. 19 shows an example of mathematical results of a neuromuscular test according to the present invention.

Fig. 20 shows an example of learning curves produced with the system according to the present invention.